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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 7 : H04B 7/005

A1

(11) International Publication Number: WO 00/25444

(43) International Publication Date: 4 May 2000 (04.05.00)

(21) International Application Number: PCT/GB99/03496

(22) International Filing Date: 27 October 1999 (27.10.99)

(30) Priority Data:
9823396.8 27 October 1998 (27.10.98) GB

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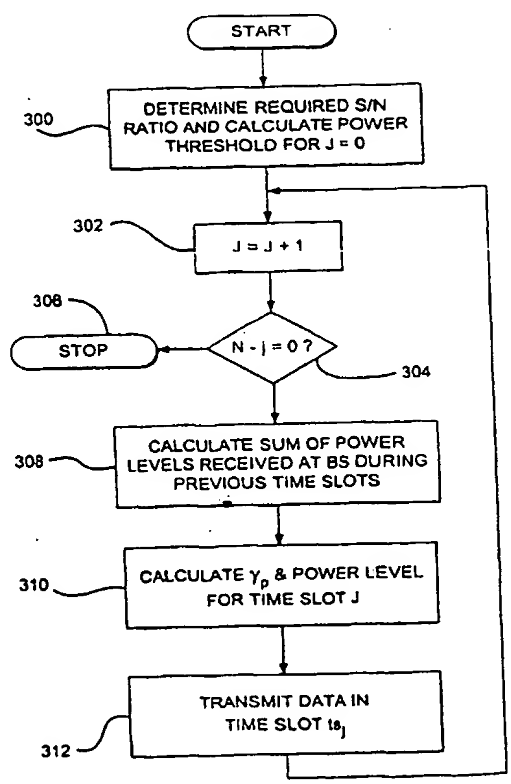
(81) Designated States: CN, JP, US, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
With international search report.

(54) Title: METHOD OF AND APPARATUS FOR POWER CONTROL

(57) Abstract

When transmitting bursty data, for example packet data, a mobile terminal uses information relating to signal strength at the base station to determine the power at which the mobile terminal must transmit in order to produce a required signal to noise ratio at the base station. In frequency division duplex techniques, multi-path fading on the down-link is uncorrelated with multi-path fading on the up-link. Power measurements can be averaged at the mobile terminal over a likely fading period. However, this does not cater for instantaneous power level fluctuations in the up-link direction, which can result in the power transmitted by the mobile terminal being too high or too low at the start of a frame. The invention maintains a predetermined signal to noise ratio. At a given time slot, a power level is determined which, over remaining time slots, is based on the sum of power levels corresponding to previous time slots and the number of time slots remaining in the frame. Where multi-path fading occurs, smaller variations in average power over the frame will occur leading to improved system capacity.



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METHOD OF AND APPARATUS FOR POWER CONTROL

The present invention relates to a method of and apparatus for power control, of the type used in a communication system, for example, in a spread-spectrum communication system, such as a Code Division Multiple Access (CDMA) communication system.

In a CDMA cellular communication system, power control is used to equalize signal to noise (S/N) ratios of the signals received at a base station from various mobile terminals. In the term 'signal to noise ratio', the term 'noise' is intended to include interference in the form of signals from other mobile terminals, as well as background noise.

A known technique involves measuring the S/N ratio in respect of signals received from a given mobile terminal over a measurement interval and comparing the measured S/N ratio against a desired threshold. If the measured S/N ratio exceeds the desired threshold, a binary 1 (or 0, depending upon the convention employed) is transmitted (within the plurality of signals transmitted from the base station) to the mobile terminal originating the given signal. If the measured S/N ratio is lower than the desired threshold, a binary 0 (or 1, depending upon the convention employed) is transmitted to the given mobile terminal. The mobile terminal, in turn, responds by reducing its transmission power by, for example, 1 dB if a 1 (or 0) is received or by increasing its power by 1 dB if a 0 (or 1) is received. In this way, the received S/N ratio is held approximately constant as path loss between the given mobile station and the base station varies and/or as the level of interference at the base station from other mobile terminals varies.

The above technique is effective in the transmission of continuous data where any transients associated with the initial setting of transmitter power at

the mobile terminal can be ignored. However, where individual bursts (frames) of data are transmitted, for example packet data, the mobile terminal must set its initial transmitter power according to a so-called open loop power control technique. In this technique, the base station signals to the mobile terminal(s) the power at which the base station is transmitting; this can be either the total power received or the power of a particular signal which the mobile(s) station is receiving, and the interference level at the base station. The mobile terminal measures the power level of the corresponding signal received from the base station and uses the signalled information, i.e. the information relating to signal strength at the base station, to determine the power at which the mobile terminal must transmit in order to produce a required S/N ratio at the base station. On average, this should be the correct power. However, in many CDMA systems the frequency used for transmission from the base station to the mobile terminal (down-link) is different from the frequency used for transmission from the mobile terminal to the base station (up-link). Such a scheme is known as a Frequency Division Duplex (FDD) technique. In an FDD technique, propagation of signals is non-reciprocal in the short term, for example, multi-path fading on the down-link is uncorrelated with multi-path fading on the up-link. This effect can be mitigated somewhat by averaging the power measurements at the mobile terminal over the likely fading period. However, this does not cater for the instantaneous path level fluctuations in the up-link direction, resulting in the power transmitted by the mobile terminal being too high or too low at the start of the frame.

In a typical CDMA system, Forward Error Correction (FEC) with interleaving is employed in order to mitigate the effects of fading and interference from other signals operating on the same frequency. If a known soft decision decoding technique is employed, the effect of the interleaving is to

make the probability of uncorrectable errors in an interleaved frame a function more of the average S/N ratio over the frame rather than, for example, the worst case S/N ratio. Consequently, if the S/N ratio at the start of a frame is too high, implementation of power control reduces the S/N ratio to the required threshold by the end of the frame, but the overall average will be higher than necessary. Conversely, if the S/N ratio at the start of a frame is too low, implementation of power control increases the S/N ratio to the required threshold by the end of the frame, but the overall average will be lower than necessary.

It is therefore an object of the present invention to obviate or at least mitigate the above described disadvantages.

According to the present invention, there is provided a method of power control in a communications system capable of transmitting a frame having a plurality of time intervals, the method comprising the steps of: selecting a time interval in respect of which a power level is to be determined; summing any previously measured power levels in respect of any time intervals preceding the selected time interval; determining the number of any remaining time intervals, and setting the power level in respect of the selected time interval based upon the sum of previously measured power levels and the number of remaining intervals in order to achieve a predetermined S/N ratio in respect of the frame.

Preferably, the power level is set during transmission of the frame in such a way as to tend to keep the received signal to noise averaged over the frame constant.

Thus, if the signal is received at a S/N ratio higher than necessary at the beginning of a frame, the method will ensure that the signal will be received at a level lower than the nominal S/N ratio by the end of the frame. Where multi-path fading occurs the use of this method will result in smaller variation in average power over the frame, leading to an improvement in system capacity.

This differs from known techniques which try to modify the power level within each time interval so as to substantially keep to the predetermined signal to noise ratio during each interval.

Preferably, the time interval is a time slot.

At least one embodiment of the invention will now be described by way of example, with reference to the accompanying drawings, in which:

FIGURE 1 is a schematic diagram of the entities used in a communications system,

FIGURE 2 is a schematic diagram of a frame used by the system of Figure 1, and

FIGURE 3 is a flowchart of a method constituting an embodiment of the present invention.

Referring to Figure 1, a CDMA system comprises at least one base station 102 supporting a cell 104, the base station 102 being arranged to communicate with a mobile terminal 106 over a radio-frequency (RF) interface 108 by transmitting a frame 200 of data (Figure 2). The frame 200 comprises N time slots ts_0, ..., ts_{N-1}.

In operation, the frame 200 is transmitted from the mobile terminal 106 to the base station 102, during which power control is achieved by N adjustments of power corresponding to N time slots in the frame 200.

Referring to Figure 3, a required average S/N ratio γ_d at the base station 102 over the duration of the frame 200 is initially determined and set (step 300). A power level is then set so that the average S/N ratio γ_d per time slot at the base station 102 will be substantially met (step 300).

A subsequent time slot, ts_j, for which the power level is to be adjusted, is then selected (step 302) and the number of any remaining time slots, N-j, is determined (step 304). If the number of time slots remaining, N-j, is zero, no

further power levels are set for the frame 200 (step 306). If, however, one or more time slots remain, the sum of respective measured power levels received at the base station 102 during previous time slots is calculated (step 308). The calculation can be generally expressed as: $\sum_{i=0}^{j-1}\gamma_i$, where γ_i is the S/N ratio received in the ith slot.

Using the sum of the measured power levels, the predetermined average S/N ratio γ_d and knowledge of the number of remaining time slots, a predicted S/N ratio, γ_p is then calculated (step 310) and the value of γ_p is used to calculate the power level at which the mobile terminal 106 transmits signals to the base station 102. The equation used to calculate the predicted S/N ratio γ_p is derived as follows.

The predicted S/N ratio γ_p is calculated based upon the assumption that a target, of the average S/N ratio, γ_d, across the frame 200, will be met if the calculated predicted S/N ratio γ_p is maintained throughout the remainder of the frame 200, thereby keeping the average S/N ratio γ_d substantially constant over the frame 200.

Since N-j power control intervals (time slots) remain in the frame 200 for which a power level is to be predicted, in order to satisfy the S/N ratio requirement of $N\gamma_d$ for the entire frame 200, the predicted S/N ratio γ_p for the remaining intervals, γ_p needs to satisfy the following equation:

$$\sum_{i=0}^{j-1}\gamma_i+(N-j)\gamma_p=N\gamma_d$$

Thus, the above equation is solved for γ_p and hence the predicted required power level (and therefore the next threshold) is calculated using the following equation:

$$\gamma_p = \frac{N\gamma_d - \sum_{i=0}^{j-1} \gamma_i}{N - j}$$

During the selected time slot, ts_j, the mobile terminal 106 transmits at the power level set (step 312) corresponding to the associated predicted S/N ratio γ_p.

A subsequent time slot is then selected (step 302) and the above-described procedure for calculating and setting power levels is repeated (steps 304 to 312).

Minor obvious modifications can be made within the normal ability of a skilled person to take account of non zero periods for measurement and for signalling within the power control sub-system.

Claims:

1. A method of power control in a communications system capable of transmitting a frame having a plurality of time intervals, the method comprising the steps of:

selecting a time interval in respect of which a power level is to be determined;

summing any previously measured power levels in respect of any time intervals preceding the selected time interval;

determining the number of any remaining time intervals; and

setting the power level in respect of the selected time interval based upon the sum of previously measured power levels and the number of remaining intervals so as to achieve a predetermined signal to noise ratio in respect of the frame.

2. A method according to Claim 1, wherein the power level setting step takes place during transmission of the frame.

3. A method according to Claim 1, wherein the power level setting step keeps the received signal to noise ratio averaged over the frame substantially constant.

4. A method according to Claim 1, wherein the time interval is a time slot.

5. A method according to Claim 1, wherein the communications system is a spread spectrum communications system.

6. A method according to Claim 5, wherein the spread spectrum communications system is a CDMA communications system.

7. A method according to Claim 6, wherein the power level setting step achieves a signal to noise ratio, γ_p, which is given by the formula:

$$\gamma_p = \frac{N\gamma_d - \sum_{i=0}^{j-1} \gamma_i}{N - j}$$

wherein γ_i is the S/N ratio received at the base station in the ith interval; $\sum_{i=0}^{j-1} \gamma_i$ is the sum of S/N ratios received corresponding to previous time intervals; and $N\gamma_d$ is the desired total S/N ratio sum over the frame.

8. A method substantially as hereinbefore described with reference to Figure 3.

Fig. 1

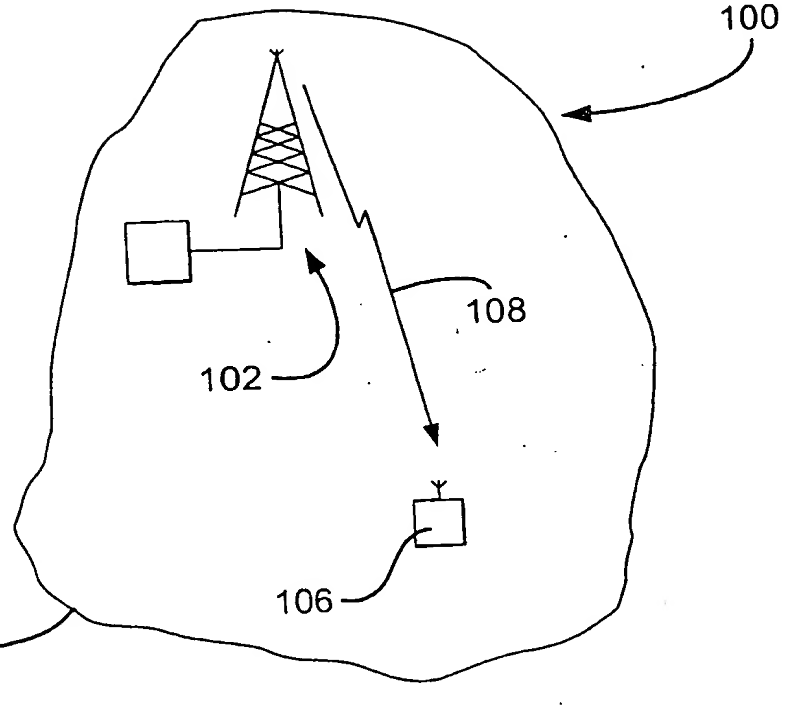


Fig. 2

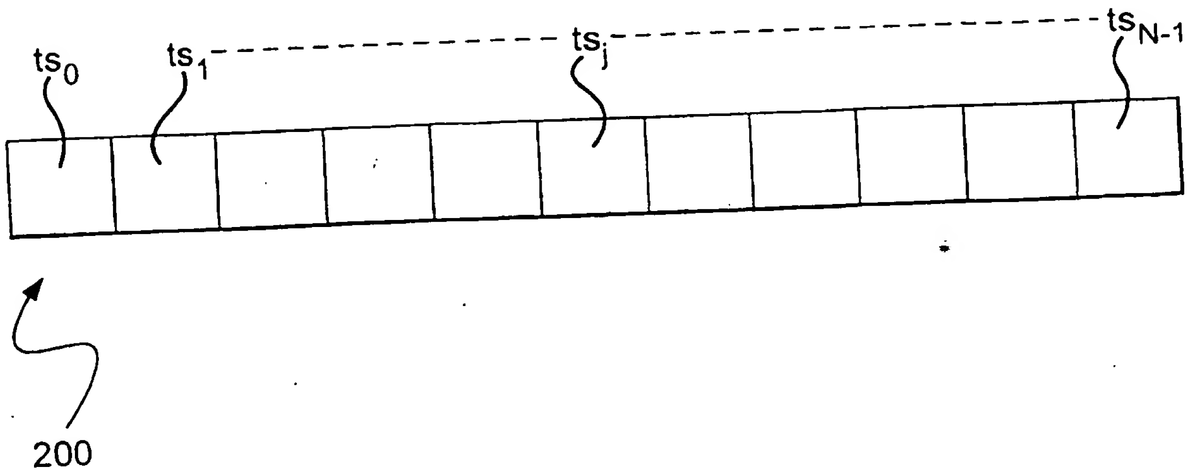
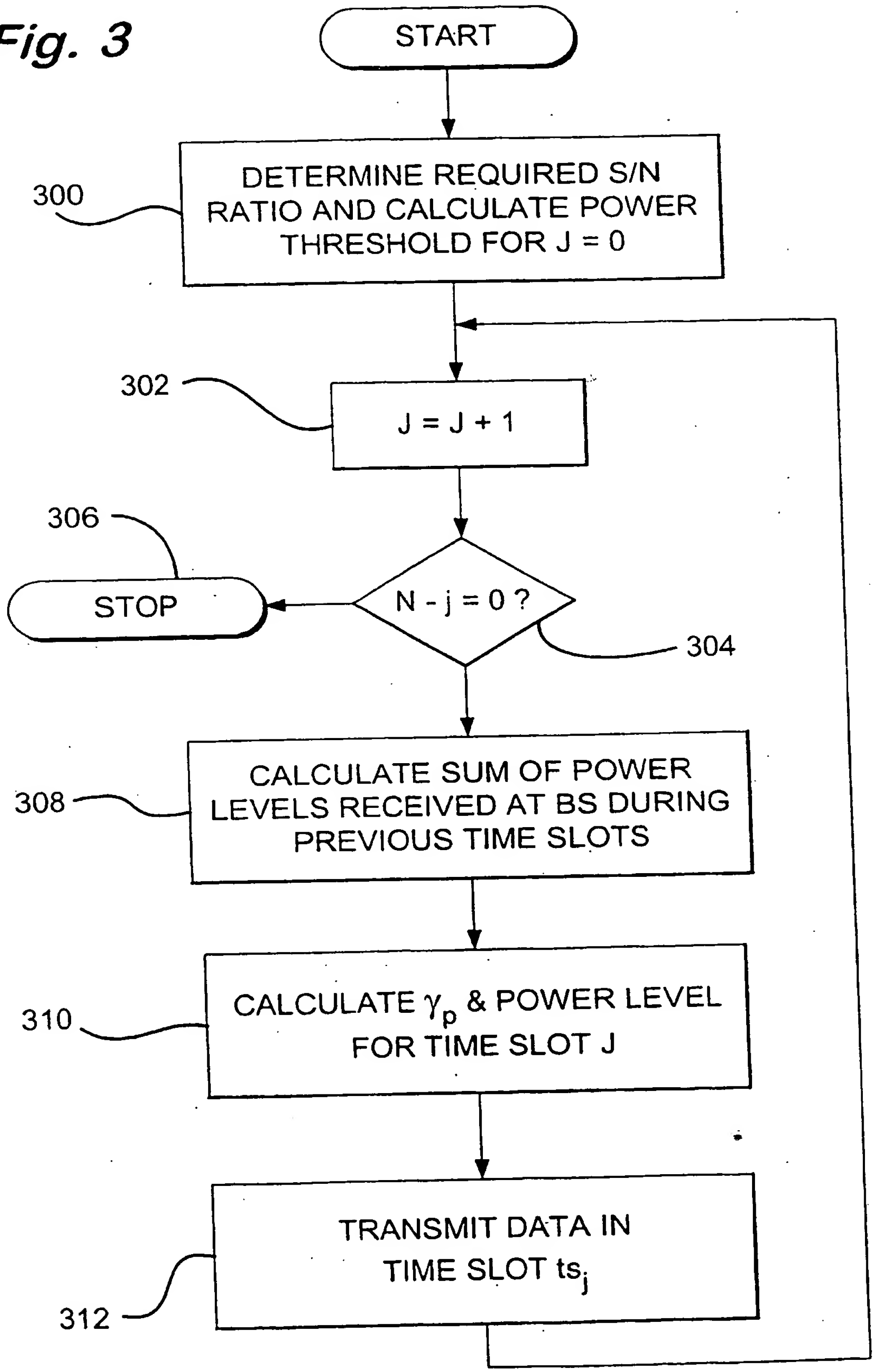


Fig. 3


START
DETERMINE REQUIRED S/N RATIO AND CALCULATE POWER THRESHOLD FOR J = 0
300
J = J + 1
302
N - j = 0 ?
304
STOP
306
CALCULATE SUM OF POWER LEVELS RECEIVED AT BS DURING PREVIOUS TIME SLOTS
308
CALCULATE γ_p & POWER LEVEL FOR TIME SLOT J
310
TRANSMIT DATA IN TIME SLOT ts_j
312

INTERNATIONAL SEARCH REPORT

Inter nal Application No
PCT/GB 99/03496

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04B7/005

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

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C. DOCUMENTS CONSIDERED TO BE RELEVANT

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A	US 5 305 468 A (BRUCKERT EUGENE J ET AL) 19 April 1994 (1994-04-19) abstract column 3, line 29 -column 5, line 56 claims 1-3 figures 5-7 ---	1,8
A	WO 97 17769 A (MARTIN PAUL MAXWELL ;IONICA INT LTD (GB); GOODINGS RUPERT LESLIE A) 15 May 1997 (1997-05-15) page 1, line 13 -page 4, line 19 claims 1,2 ---	1,8

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

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Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
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